NPS-MA-95-004

NAVAL POSTGRADUATE SCHOOL
Monterey, California

JANUS MODELING FOR THE ENVIRONMENTAL EFFECTS FOR DISTRIBUTED INTERACTIVE SIMULATION (E^2DIS) PROGRAM

by

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April 1995

Report for Period
October 1993 - February 1994

Approved for public release; distribution unlimited

Prepared for: Naval Postgraduate School
Monterey, CA 93943

NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93943

This report was prepared in conjunction with research conducted for the Naval Postgraduate School and funded by the Naval Postgraduate School.

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DTIC TAB	☐
Unannounced	☐
Justification	
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Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
April 1, 1995

3. REPORT TYPE AND DATES COVERED
Technical Report Oct 1993 - Feb 1994

4. TITLE AND SUBTITLE
Janus Modeling for the Environmental Effects for Distributed Interactive Simulation (E^2DIS) Program

5. FUNDING NUMBERS

6. AUTHOR(S)
Bard K. Mansager

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER
NPS-MA-95-004

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
TRAC - Mtry
Naval Postgraduate School
Monterey, CA 93943

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
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14. SUBJECT TERMS
Distributed Interactive Simulation, Janus Combat Simulation

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

Janus Modeling For The Environmental Effects For Distributed Interactive Simulation (E^2DIS) Program

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ABSTRACT

The Defense Modeling and Simulation Office (DMSO) has initiated a research effort to promote joint service standards for physics based environmental effects in the existing distributed modeling and simulation networks. Collectively, the project is known as Environmental Effects for Distributed Interactive Simulation (E^2DIS). Research detailed in this report was within the E^2DIS model to simulate the environmental effects on weapons systems and study the resultant force-on-force interplay. In order to do this, a scenario was developed using Fort Hunter Liggett, California terrain. In this scenario, Unmanned Aerial Vehicles (UAVs) were used to search for a Ground Launched Cruise Missiles (GLCM) and SCUD Theater Ballistic Missiles (TBMs) and Transporter Erector Launchers (TELs). Once located, a Fiber Optic Guided Missile (FOG-M) was fired at the TEL. Weather parameters were changed and the scenario was repeated. Differences between the number of TEL detections in different weather conditions were recorded.

1 Introduction

Realistic simulation of a dynamic virtual battlefield environment, combatants, and the responses of virtual sensor systems require the use of high resolution models. Current warfighting models lack the incorporation of high fidelity environmental effects and hence the full potential of these models is not realized. The Defense Modeling and Simulation Office (DMSO) has initiated a research effort to promote joint service standards for these physics based environmental effects in the existing distributed modeling and simulation networks. Collectively, the project is known as Environmental Effects for Distributed Interactive Simulation (E^2DIS).

Research detailed in this report was within the E^2DIS Demonstration Task effort. This effort used the Janus(A) combat model to simulate the environmental effects on weapons systems and study the resultant force-on-force interplay. In order to do this, a scenario was developed using Fort Hunter Liggett, California terrain. In this scenario, Unmanned Aerial Vehicles (UAVs) were used to search for a Ground Launched Cruise Missiles (GLCM) and SCUD Theater Ballistic Missile (TBM) Transporter Erector Launchers (TELs). Once located, a Fiber Optic Guided Missile (FOG-M) was fired at the TEL. Weather parameters were changed and the scenario was repeated. Differences between the number of TEL detections in different weather conditions were recorded.

This report will first briefly describe the E^2DIS program, focusing on the Demonstration Task Area. Next, the scenario will be presented. Section 4 presents a discussion of the model representation of the UAVs with different sensor packages. The weather parameters used in Janus(A) are described in Section 5. The report concludes with the results of this effort and future modeling directions to support the E^2DIS program.

2 E^2DIS Program

Currently models and simulations lack the ability to incorporate high fidelity environmental effects into their model structure. This is perceived as a major limitation hindering the realism of the existing combat models and simulations. In May 1992, DMSO established as a major goal the development of synthetic environments. This product will allow environmental data that are varying with respect to time and space, such as terrain, atmosphere, and ocean effects, to be incorporated into the model.

The E^2DIS Program Office has established a Program Development Plan (PDP) detailing how the above goal will be achieved. The PDP subdivides the mission into seven task areas: Architecture, Standards, Environmental Representations, Environmental Effects and Processes, Survey of Requirements and Capabilities, Demonstration and Management and Integration. This research was part of the Demonstration Task Area [1, p 56].

The PDP states that the objective of the Demonstration Task Area is: to plan, design, construct and conduct the demonstration of the effects of realistic environments on weapon system performance through the incorporation of environmental models and processes into Distributed Interactive Simulations integrated with real-time, force-on-force, field exercises.

The PDP lists detailed requirements and characteristics of the Task Area which are given in Appendix A.

The objective of the E^2DIS initial simulation is to demonstrate the DIS-compatible integration of realistic environmental and sensor models and to show their effect on detecting targets. Figure 1 portrays the interaction of ground players and the E^2DIS Architecture during the initial scenario.

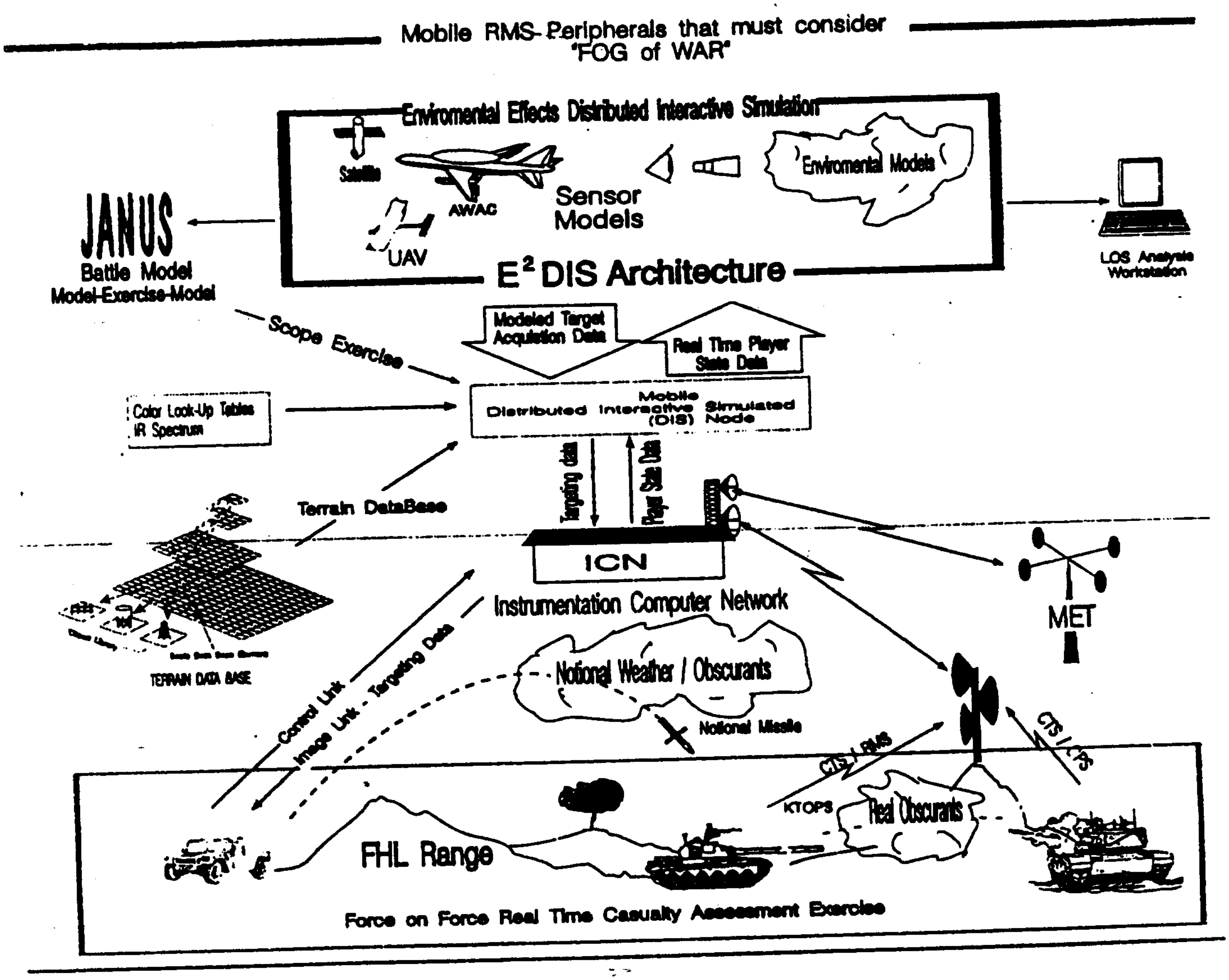

Figure 1: E^2DIS Components

To elaborate, actual ground players at Fort Hunter Liggett represented GLCM and TBM threat units. These entities were instrumented with position location systems and provided "live" player location data to the "simulated" players. Additionally, the "live" forces were video recorded to collect actual dust and vehicle-generated smoke information. "Simulated" players including UAV's, an Advanced Infrared Warning System (AWS) satellite in geostationary orbit, and one E2C aircraft with Aircraft Surveillance Radar (ASR) were all positioned to observe the TBM and GLCM launch area. There was a simultaneous exchange of data between the "live" players and the "simulated" players. Real time "live" player location data is communicated into the E^2DIS Architecture and target acquisition data from the "simulated" players is communicated to the "live" ground players at Fort Hunter Liggett. The scenario captures the interplay of "simulated" players reacting to real time position location data and the "live" players making appropriate responses to "simulated" acquisitions. The scenario is outlined in the next section.

Janus was used to develop and improve the initial scenario. It also provided the UAV component to the "simulated" players. In that role, Janus was used to demonstrate environmental effects on the UAV performance using generic clear and foggy weather.

3 Scenario

The scenario was intended to parallel the Operation Desert Storm experience in trying to find SCUD missile launchers. The terrain used was Fort Hunter Liggett, California which included a threat force of Al Hussein class theater ballistic missiles (TBMs), SSC-4 class ground-launched cruise missiles (GLCMs) and associated Transporter Erector Launchers (TELs). Friendly forces had determined that there is a high probability of a missile attack and had begun to search the enemy terrain capable of hiding missile launchers.

The search was accomplished by using Unmanned Aerial Vehicles (UAV) flying over the most likely locations that could support TBMs and associated equipment. The modeling of the UAVs will be discussed in greater detail in the next section. The AWS satellite and the E2C aircraft were not played in the Janus scenario. UAVs used a search pattern shown in Figure 2.

It was assumed that TELs had to be located in close proximity to a hard surface road and required a relatively flat, unobstructed area to launch. This limited the search to the valley areas at Fort Hunter Liggett increasing the probability of TEL detection, particularly when the TELs were moving or at a launch site. These areas of likely launch are known as "launch buckets". UAVs provided continuous coverage in the search area using on station relief by other UAVs.

The three TBM TELs and one GLCM TEL were tactically employed as depicted in Figure 3 below. This figure shows the beginning location of each system indicated by the red icon. The scenario began with the TELs being armed, fueled and ready to launch. The GLCM TEL launched four GLCMs in succession and then each of the TBM TELs launched its missile at one minute intervals. After launching its missile(s), the TELs proceeded to the hide position at the end of the orange "trail". Also depicted on Figure 3 is a number below the icon representing a timing node that keeps the system in the start position for the number

of indicated minutes. When the simulation's clock reaches that point of time, the TEL begins movement along the orange path and terminates in its hide position. Consequently, the 3, 4, and 5 allows the model to play the subsequent launches by the TBM TELs. Additionally, a command and control element for the launchers was included as a player and positioned on high ground to insure radio communication with the launch sites.

UAVs were able to detect the TELs while they were in their launch location or while transiting to their hide positions. Five minutes following such a detection, a Fiber Optically Guided Missile (FOG-M) was fired at the detected system [2].

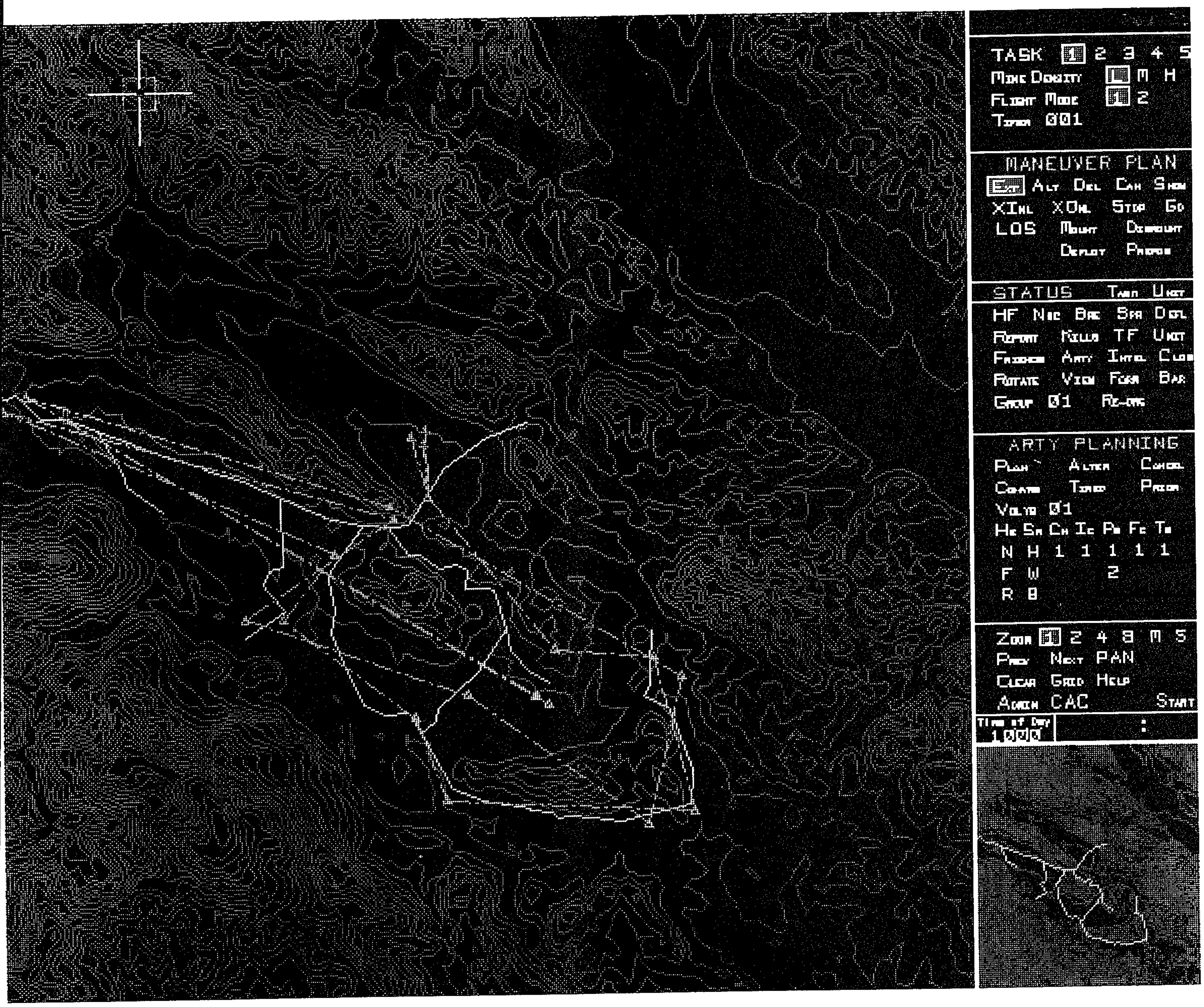

Figure 2: UAV Search Patterns

A,B,C: TEL Fire/Hide Locations,
TEL Movements

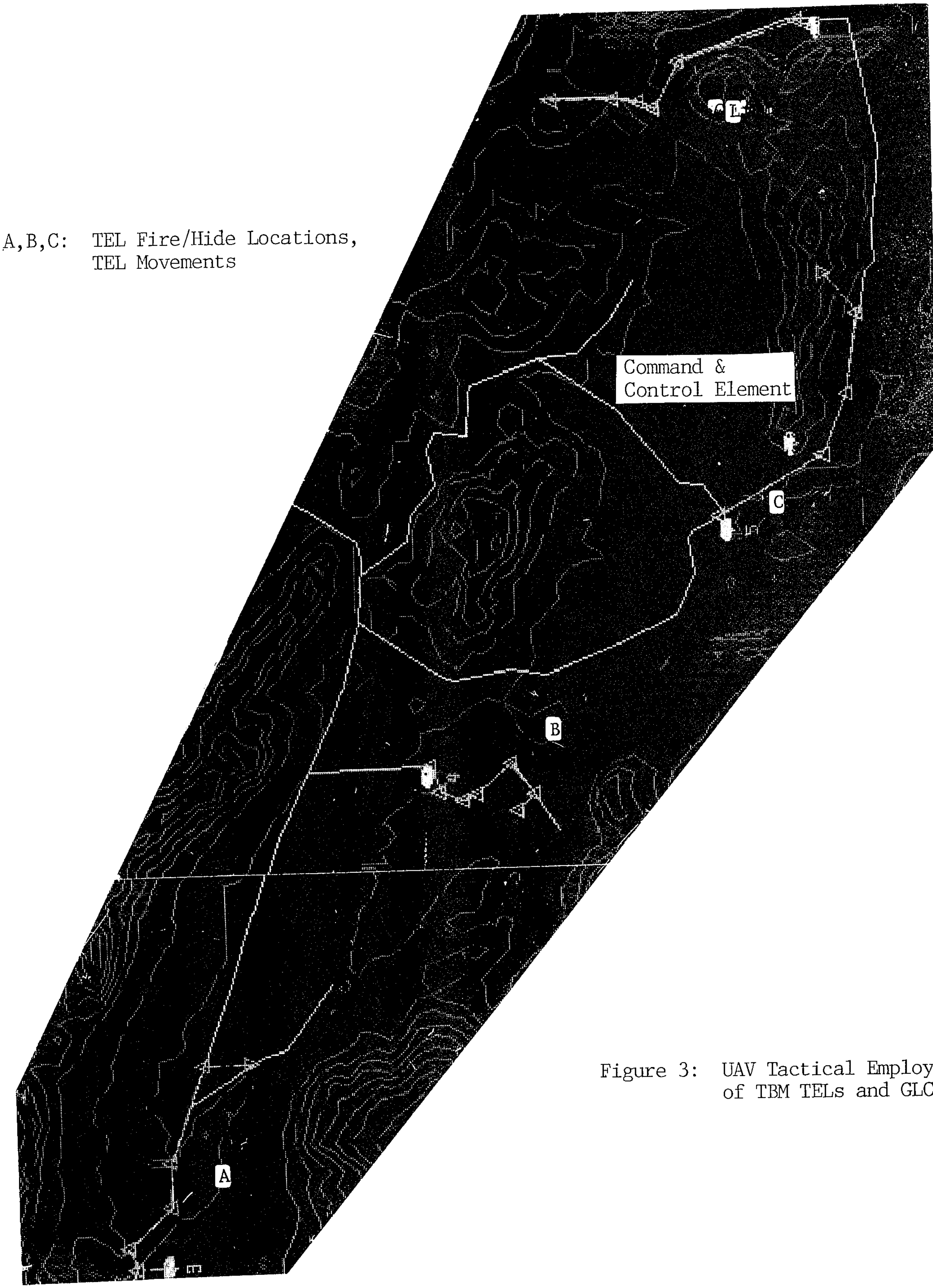

Figure 3: UAV Tactical Employment of TBM TELs and GLCM

4 UAV Model

The Pioneer system shown in Figure 4 was selected as the UAV to be modeled in this scenario. The Pioneer can operate between 60 and 95 knots for up to five hours at altitudes to 12,000 feet. It has an operational range of over 100 NM from its Ground Control Station (GCS). The system was used in Operation Desert Storm where its mission range was between 20 to 80 NM at altitudes from 2500 to 5500 feet. Typical missions used the Pioneer for both day and night reconnaissance, surveillance, targeting, gunfire spotting and battle damage assessment. Both the radar cross section (RCS) and its IR signature make the Pioneer difficult to detect [3].

The Janus model representation of the Pioneer aircraft used an altitude of 1524 meters (5000 feet) and a velocity of 60 knots. Both of these parameters remained constant throughout the simulation. Janus also incorporates data for an enemy system detecting the UAV. In this scenario, Pioneer used a minimum detection dimension of one meter. This value is the smallest of the system's length, height or width. One meter was the width of the Pioneer. Janus also allows a parameter to be entered for the system's Thermal Contrast Class. This measures the difference in degrees Centigrade between the system and its background and ranges in value from .5 to 7.0 C. The lower the value, the smaller the contrast and hence the greater difficulty to detect [4]. This scenario used a value of 1.0 C. Modeled values adequately portray the RCS and IR signature for the Pioneer.

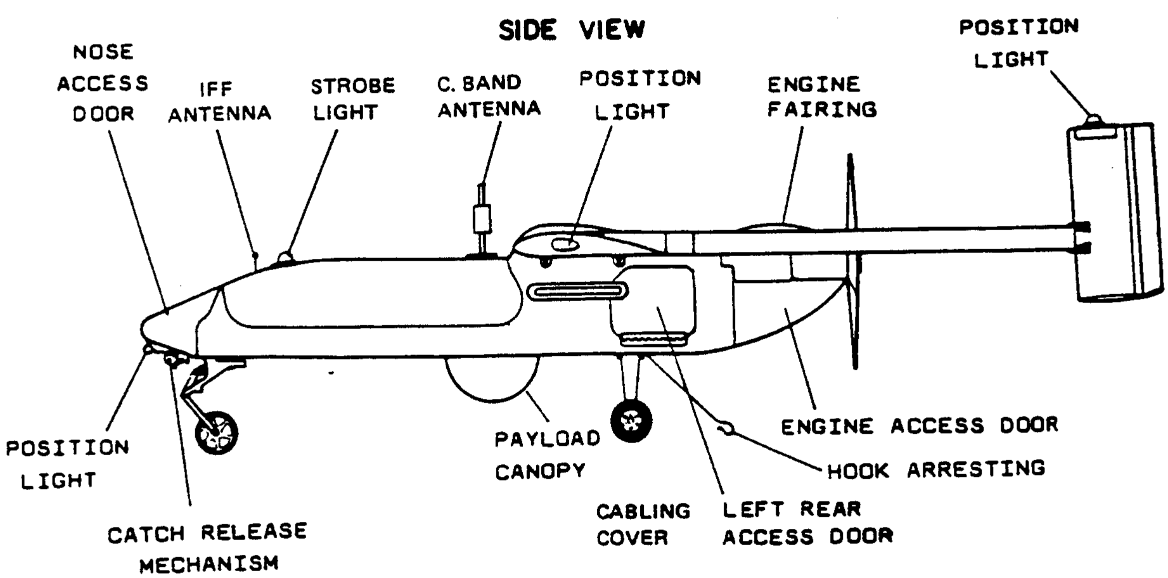

Figure 4: Pioneer UAV

The Pioneer has the capability of carrying different sensor packages. An optical sensor is used for day reconnaissance missions and thermal sensors are used in night or low visibility. The scenario used both optical and thermal sensors to gather detection data. Each sensor is modeled with a narrow and wide Field of View (FOV). The sensor initially searches using the wide view and switches to the narrow FOV when a detection occurs to further classify the target [4]. Data for the two UAVs played in this scenario are provided in Table 1 below.

Table 1: UAV Sensor Packages

FOV (degrees)			
UAV #	Narrow	Wide	Spectrum
1	5.0	10.0	Thermal
2	5.1	10.0	Optical

5 Weather Implications

During this project, Janus was used to demonstrate a difference in UAV detections during "good" and "bad" weather conditions. Janus has the capability of representing up 16 different weather options. Nine of these options are standard weather characteristics used in frequently occurring US Army scenarios. The Weather/Location Selection Screen for these Janus options is located in Appendix B. The "good" weather was represented by The Summer - 16.9 Km visibility - Desert Environment and the "bad" weather being Winter - 2 KM Visibility - Plains Environment. Exact data for each specific Weather Type is given in Appendix C [4].

Ten scenario runs were made for both weather types. Each run had both optical and thermal sensor packages on the UAV. To evaluate the difference several Measures of Performance (MOPs) were selected: the Mean Detection Range, the Number of Detections, Maximum Detection Range and the Minimum Detection Range. The collected data is summarized in Tables 2 and 3 below.

Table 2: MOP Results for Optical Sensor

MOP	Good Weather	Bad Weather
Mean Detection Range (Km)	1.735	0.545
Number of Detections	109	21
Max Detection Range (Km)	6.259	.601
Min Detection Range (Km)	.513	.511

Table 3: MOP Results for a Thermal Sensor

MOP	Good Weather	Bad Weather
Mean Detection Range (Km)	2.166	1.645
Number of Detections	33	11
Max Detection Range (Km)	4.686	1.737
Min Detection Range (Km)	1.601	1.607

The data show a pronounced difference for detections in good and bad weather for both the Mean Detection Range and the Number of Detections MOPs (by an order of magnitude for the optical sensor). The weather effect is also demonstrated in the Maximum Range of Detection for both sensors. The only MOP where the weather did not show a significant difference was for Minimum Range of Detection. This is not unreasonable since the values for this MOP are close to the minimum distance between the UAV's flight path and the TEL positions regardless of weather condition. The weather effects portrayed in Janus had a demonstrated and quantifiable effect upon UAV detections.

6 Conclusions

This research demonstrated the ability of Janus to develop a tactical scenario for use within the DIS environment. It further showed its ability to realistically portray UAVs in an operational scenario. All the important characteristics of the Pioneer UAV were captured within the Janus database. Finally, the two weather conditions used demonstrated Janus' capability to capture the environmental effects upon UAV detection performance. Again, the database structure allows a wide variety of weather conditions to be represented within the Janus simulation.

Future research work should incorporate actual weather and illumination parameters provided by Army Research Laboratory (ARL) and TRADOC Analysis Center - White Sands Missile Range (TRAC-WSMR) to measure their effects on detection MOPs. Additionally, the performance of UAVs within the Janus model, using a one meter terrain database should be investigated.

7 References

1. Defense Modeling and Simulation Office, "Environmental Effects for Distributed Interactive Simulation (E2DIS) Project Development Plan," 30 June 1993.
2. DeJonckheere, Richard, "Scenario for Initial E^2DIS Demonstration Working Group," Phillips Laboratory, Kirtland AFB, New Mexico, December 1993.
3. Soutter, Paul A., "On the Use of Unmanned Aerial Vehicles To Search for Tactical Ballistic Missile Transporter-Erector-Launchers," Master's Thesis, Naval Postgraduate School, Monterey, California, March 1994.
4. Department of the Army, "The Janus 3.X/UNIX Model User's Manual," TRADOC Analysis Center, Fort Leavenworth, Kansas, 1993.

Appendix A

1.0 SUMMARY DESCRIPTION AND PURPOSE OF TASK AREA

1.1 Requirements

The objective of this task area is to plan, design, construct and conduct the demonstration of the effects of realistic environments on weapon system performance through the incorporation of environmental models and processes into Distributed Interactive Simulations integrated with real-time, force-on-force, field exercises. This will require simulation of:

- High-fidelity, first-principle physics descriptions of the terrain, atmosphere (ground to space), and weather;
- RF/MMW/IR/VIS/UV signals generated by man made and natural objects and their propagation through the environments;
- Scenes of backgrounds, foregrounds and imbedded targets incident on sensor apertures/antennas;
- Scene/signal processing through selected sensor subsystem modules;
- Communication of the processed data/signals to interested users;
- Output of processed data/signals on weapon system screens/displays; and
- Response of a human-in-the-loop or unmanned vehicle in the loop.

Atmospheric/terrain models, effects, and processes that should be demonstrated include:

- Ionospheric, magnetospheric and other space environments;
- Atmospheric profiles of temperature, density, and pressure (special topics include the stratosphere, tropopause, jet streams, and other local/regional and diurnal/annual variations);
- Aerosols — dust, pollution, smoke, smog, and haze;
- Humidity/moisture/precipitation — clouds, rain, fog, drizzle, snow, icing, and storms,
- Atmospheric turbulence and winds;
- Terrain features — roughness/distribution, discretes, cultural features; and
- EO/EM propagation effects — absorption, attenuation, scattering, scintillation, refraction, diffraction, temporal and spatial structure, in-band emittance and transmittance, *etc.* due to atmospheric constituents.

Important characteristics of these simulations that will also be addressed include:

- Dynamic scalability of the environmental simulations (*i.e.*, the fidelity or level of spatial, temporal, and spectral structure);
- Sensitivity of system response to the approach for modeling certain environmental effects (*i.e.*, gridded versus feature-based);
- Simultaneity and consistency between the environmental description, the combatant state truth data, and the virtual battlefield description; and
- The degree of fidelity required for sensor and subsystem response.

Appendix B

Section 6: Weather Data

From the Combat Systems Data Editor menu screen, Figure 2.2, select WW to access the Weather/Location Selection screen, Figure 2.101.

Figure 2.101 Weather/Location Selection Chart Screen

xterm

WEATHER / LOCATION SELECTION

WNT-7KM-PLAINS	....	Option	1
WNT-14KM-DESERT	....	Option	2
SMR-14KM-DESERT	....	Option	3
SMR-5KMSD-DESERT	....	Option	4
SMR-14KM-PLAINS	....	Option	5
WNT-2KM-PLAINS .	....	Option	6
WNT-14KM-PLAINS	....	Option	7
SPR-8KM-JUNGLE	....	Option	8
SPR-3KMRN-DESERT	....	Option	9
	....	Option	10
	....	Option	11
	....	Option	12
	....	Option	13
	....	Option	14
	....	Option	15
	....	Option	16

SELECT OPTION -> XX

This screen permits selection of one of the sixteen possible weather options for data entry/editing.

Appendix C

WEATHER TYPE,NAME: SUM-16.9KM DESERT

Visibility...16900
Wind Direction(Deg from X-Axis,CCW)..............165
Wind Velocity (Km/Hr)......................................20.8

EOSAEL Xscale Atmospheric Model (1-4).......3
Air Mass Type (1=ma,2=mp,3=cp)...............3

Ceiling (Above ground Level,meters)...............2360
Relative Humidity (0.0 - 1.0)............................0.34
Temperature(Farenheit)..................................74.8
Inversion Factor (0 - 5)..................................3

Extinction Coef, Band 1	0.2930	Sky-To-Ground Brightness Ratios	
Extinction Coef, Band 2	0.1490	0 Degrees	2.2
Extinction Coef, Band 3	0.2220	45 Degrees	2.2
Extinction Coef, Band 4	0.1270	90 Degrees	2.2
Optical Contrast	0.35	135 Degrees	2.2
Sun Angle (Deg)	0.001	180 Degrees	2.2

WEATHER TYPE,NAME: 2KM FOG-PLAINS

Visibility...2000
Wind Direction(Deg from X-Axis,CCW)..............15
Wind Velocity (Km/Hr)......................................6.5

EOSAEL Xscale Atmospheric Model (1-4).......1
Air Mass Type (1=ma,2=mp,3=cp)...............3

Ceiling (Above ground Level,meters)...............180
Relative Humidity (0.0 - 1.0)............................0.93
Temperature(Farenheit)..................................28.5
Inversion Factor (0 - 5)..................................2

Extinction Coef, Band 1	1.9500	Sky-To-Ground Brightness Ratios	
Extinction Coef, Band 2	2.0340	0 Degrees	5.8
Extinction Coef, Band 3	2.6470	45 Degrees	5.8
Extinction Coef, Band 4	0.6770	90 Degrees	5.8
Optical Contrast	0.35	135 Degrees	5.8
Sun Angle (Deg)	0.45	180 Degrees	5.8

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